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WALLACE H. COULTER SCHOOL OF ENGINEERING
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MEMORANDUM

From: Bill Jemison
To: Dr. Daniel Tam, ONR
Date: 6/30/2011

Subject: Progress Report 003– Chaotic LIDAR for Naval Applications (4/1/2011– 6/30/11)

This document provides a progress report on the project "Chaotic LIDAR for Naval Applications" covering the period of 4/1/2011–6/30/11.

Staffing: Mr. Luke Rumbaugh joined the project on June 15th 2011. Mr. Rumbaugh is a Ph.D. student at Clarkson University. Mr. Rumbaugh graduated with honors from Grove City College with at BS in electrical engineering. He has also completed a number of graduate courses at Rochester Institute of Technology. He spent 1.5 years working at John Hopkins APL as a radar engineer and 2.5 years working designing electrical systems for the health care industry.

Technical Progress:

- 1550 Fiber Ring Laser - The last progress report described a proof-of-concept fiber ring laser that was constructed using existing components at a wavelength of approximately 1546 nm. This wavelength was selected due to the availability of all necessary fiber laser components. This laser is capable of lasing in multiple modes simultaneously and the temporal output is noise-like with a well-defined autocorrelation peak. While we are not pursuing a frequency doubled 1546 nm laser since we don't believe the wavelength (773 nm) is appropriate for underwater work, we will continue to work with this laser to help us explore autocorrelation-based signal processing approaches (described in more detail below). Figures 1 and 2 show additional characterization of the fiber ring laser. Figure 1 shows the optical spectrum of the fiber ring laser. As desired, the laser output consists of many lasing modes occurring over a 1nm bandwidth defined by the fiber Bragg grating used in the laser cavity. This results in a broadband RF signal upon photo-detection as shown in Figure 2. This RF spectrum has a very flat frequency response from 200 MHz to 4.4 GHz (which is the limitation of the existing measurement equipment) as desired.

  In summary, we are now obtaining a broadband laser output as desired which allows us to investigate the chaotic dynamics and to explore proof-of-concept autocorrelation-based signal processing approaches as we simultaneously move towards the development of a 1060 nm fiber ring laser that can be frequency doubled to a useful underwater wavelength of 530 nm. While autocorrelations can be obtained using digital techniques, it also is desired to develop optical techniques to perform the autocorrelation in real-time, thereby enabling a real-time proximity sensing circuit. A

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block diagram of an experiment that is in progress is shown in Figure 3. In this experiment a portion of the chaotic laser will be tapped off and sent through a fiber delay of τ seconds. The primary output of the laser will be transmitted to a target. Both the tapped output and the target return will be sent to optical detectors. The detector outputs will then be mixed and integrated to form the autocorrelation. An autocorrelation peak should occur when the distance to the target is $\tau/2$.

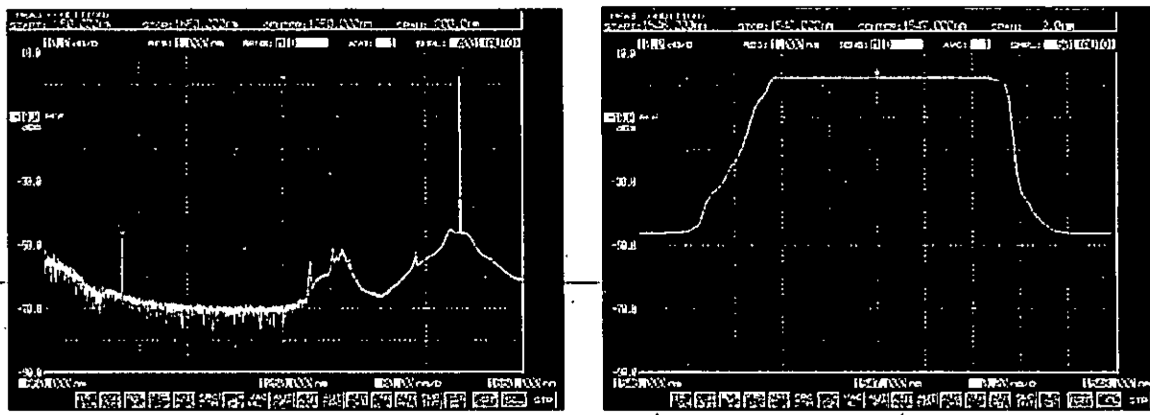

Figure 1. Left Plot: Optical spectrum of the fiber ring laser showing the pump wavelength at 980 nm and output wavelength at 1546 nm. Right Plot: Optical spectrum shown the detail of the output wavelength. Lasing is occurring over a 1 nm bandwidth defined by the fiber Bragg grating.

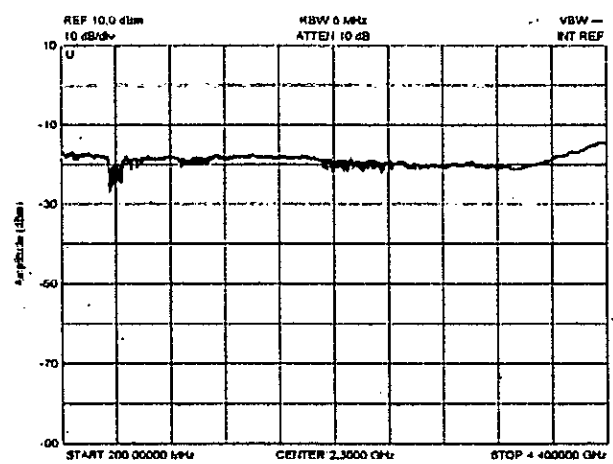

Figure 2. RF spectrum of the photo-detected output of the 1543nm fiber ring laser. The broad RF bandwidth is a result of the multiple longitudinal lasing modes.

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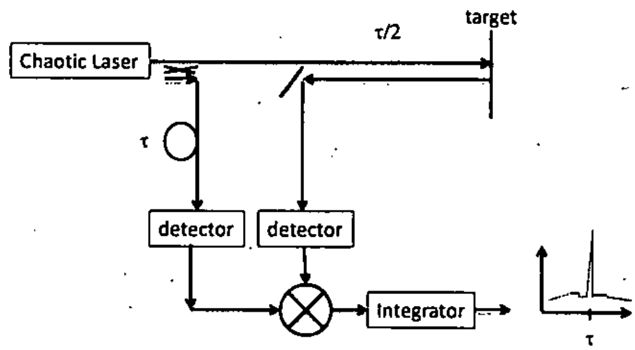

Figure 1. Autocorrelation experiment in-progress

- 1060 nm Fiber Ring Laser - We have begun designing a fiber ring laser at 1060 nm. A double-clad fiber approach is being considered to support high power operation. A frequency doubled 1060 nm laser would operate at 530 nm; a wavelength that is suitable for underwater operation. Therefore, our investigations into frequency doubling are focusing on the 1060 nm laser.

- Chaotic Laser Simulation - We have also investigated approaches to simulating chaotic fiber laser performance. There are two fiber laser simulation programs that are available commercially and we had originally planned to use commercially available software to assist with the laser design. However, both of these programs simulate steady state laser performance only. While steady state analysis is useful for optimizing the laser output power, it does not provide any insight into the laser dynamics including chaotic behavior. Therefore, we performed a literature search into simulation of fiber lasers. The majority of papers also only address steady state analysis. However, there is some recent work that address fiber laser dynamics. We are currently analyzing the approaches of Ray et. al. [1], Wu [2], and Shalibeik [3] and plan to select a simulation approach by the end of July.

[1] W. Ray, K. Wiesefeld, J. L. Rodgers, "Refined laser model", Physical Review E 78, 046203 (2008)
[2] T. Wu, Toward Diffraction-Limited High Power Lasers, Ph.D. Thesis, University of Michigan, 2010
[3] H. Shailbeilk, Rare-Earth-Fiber Lasers, Ph.D. Thesis, Technical University Braunschweig (2007)

Budget and Schedule:

- Clarkson submitted its first invoice of $26,284 to ONR on 3/29/2011 for the second quarter (Q2) of FY2011. A second invoice covering the third quarter of 2011 will be submitted in the amount of $28,953.07 for a total project expenditure of $55,237.

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